OCAMS Outbound Cruise and Earth Gravity Assist Caveats

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Note on the 'Icicle' Phenomenon

First, some background on commanding OCAMS: a commanded integration time of 0 msec actually corresponds to an exposure time of 1.49 msec with a static exposure time of 0.45 msec (the time that the charge buckets are stationary over their assigned pixels with the rest of the time—1.044 msec—spent traveling across the frame); same for 1 msec. For 2 msec, the actual exposure time is 2.55 msec (static time = 1.51 msec) and for 3 msec, it's 3.22 msec (2.18 msec) and so forth. (For 20 msec, it's 20.3 ms; always there's a little extra exposure time to clock the pixels down the frame). When integration time starts, the user implicitly commands a frame transfer. During the transfer, since there is not a shutter, photons, and therefore charge, are accumulated. The same happens during the frame transfer at the end of the integration time.

During integration, the user also automatically commands a configurable number of storage section and horizontal register flushes (to clear out dark current and excess charge). If that is not done, then there is bleed back into the storage areas, depending on the scene brightness. The millisecond before expiration of integration time, a final storage flush is commanded and the horizontal register itself is flushed a final time before the frame transfer. These final flushes are in time to clear all extraneous charge from the storage region for all integration times ≥ 3 msec. For commanded integration times of 0, 1 and 2 msec, these final flushes are not performed because there is not enough time.

The EGA campaign involved images of the Earth and Moon at fairly low phase angles (~30-40°) making them very bright targets relative to the design of the OCAMS imagers, especially the MapCam and PolyCam, whose speeds are around F/3. Accordingly, it was necessary to use integration times of 0 ms to properly expose the imagers without saturation. An exposure time of 3 msec (for the Pan filter), which is approximately a factor of 2 greater residence time within the exposed area of the detector, was excessive: those MapCam images were saturated during the EGA encounter.

So, for the 0 ms images, that left a certain amount of excess charge that accumulated—especially on the Earth scene, which dramatically filled the fields of view of both the PolyCam and Mapcam—and bled back into the storage section. These pixels were eventually read out as a fake "signal" which we observe as the icicle-looking phenomenon. In the columns where that scene is bright (the full Earth disk is being imaged) and therefore experiences greater charge smear, this excess charge is more of a problem than in other columns. This is visible in the flight images.

Data is not missed in these bleed-back pixels, it is saturated. The saturated pixels show up as white in the raw image. During processing they were identified and set to zero so as to be less obtrusive, but that is a processing decision which results in the dark appearance.

<u>Note on I/F</u>

It should be noted that the calculation of the L2 I/F images (in units of reflectance) depends on the amount of solar flux incident on the surface, which in turn depends on the distance from the Sun to the target. In the OCAMS calibration pipeline, the distance used is the distance from the Sun to the OSIRIS-REx spacecraft, which will be slightly different. However, for even the earliest resolved images of Bennu, the difference between the two distances is < 0.1%. For all of Proximity Operations, the difference is < 0.00001%. The only other target for which reflectance is meaningful is the Moon during the Earth Gravity Assist. For the Moon images on 09/25/2017, which have been used to radiometrically verify the cameras, the difference is ~0.5%. For the Moon images on 10/02/2017, the difference is ~3%. However in these images the Moon subtends only a few pixels, therefore it is not expected that those data will ever be used for radiometry. As a result, the OCAMS calibration pipeline will ***not*** be changed to use distance-to-target in the calculation of the I/F L2 images.

<u>Note on 2.5 ms darks</u>

The 2.5 ms images taken in EGA were mistakenly bias/dark corrected with the 1.5 ms master darks from the same period. The quantitative difference between the two is insignificant, as the amount of dark current in images with such short exposure times is << 1 DN. The read noise (~10 DN) is orders of magnitude higher than the dark current. As such, there is no impact on the images due to the incorrect darks.

The FITS headers and .XML PDS labels for the 2.5 ms images correctly indicate that they were corrected with the 1.5 ms darks. No other exposure times have mismatched darks, in EGA or any other time in Cruise.